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**Instrument Landing System  
Mathematical Modeling Study  
for Orlando International Airport  
Runway 35L Localizer, Orlando,  
Fla., Final Airside Docking Plan  
(Scheme IIIA)**

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December 1988

DOT/FAA/CT-TN89/4

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<b>16. Abstract</b>  This Technical Note describes the instrument landing system (ILS) math modeling performed by the Federal Aviation Administration (FAA) Technical Center at the request of the Southern Region. Computed data are presented showing the effects of airside terminals with simulated docked and taxiing aircraft on the performance of an ILS localizer proposed for runway 35L at the Orlando International Airport. The Southern Region is concerned that reflections from two proposed airside terminals with docked and taxiing aircraft may degrade the localizer course beyond category II/III tolerances. Modeled course structure results indicate that category II/III localizer performance should be obtained with the Wilcox Mark II, 14-element, dual-frequency log periodic antenna and both airside terminals with docked and taxiing aircraft at the currently proposed locations. Computed clearance orbit results indicate satisfactory linearity, course crossover, and signal clearance levels.			
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## EXECUTIVE SUMMARY

This instrument landing system (ILS) math modeling study was performed at the request of the Southern Region to compute the effects of two airside terminals with docked and taxiing aircraft on the performance of an ILS localizer proposed for runway 35L which is under construction at the Orlando International Airport. Reflections from other structures on the airport are not considered in this modeling study. The localizer was modeled using a physical optics mathematical model developed by the Transportation Systems Center. As requested by ASO-433, a Wilcox Mark II, 14-element, dual frequency log periodic antenna array was modeled. Derogative effects from the two airside terminals and simulated docked and taxiing aircraft in several reflecting source configurations were considered. Modeled course structure results indicate that category II/III localizer performance should be obtained for runway 35L with both airside terminals and docked and taxiing aircraft at the currently proposed locations. Computed clearance orbit results indicate satisfactory linearity, course crossover, and signal clearance levels.

## INTRODUCTION

### PURPOSE.

The purpose of this math modeling study was to provide computer modeled performance data for an instrument landing system (ILS) localizer proposed for runway 35L at the Orlando International Airport.

### BACKGROUND.

The Southern Region will be installing an ILS localizer to serve runway 35L which is under construction at the Orlando International Airport. In support of this project, ASO-433 has requested a math modeling study through the Navigation and Landing Division, APS-400, which, in turn, was forwarded to the Federal Aviation Administration (FAA) Technical Center for accomplishment. Localizer math modeling was requested for a Wilcox Mark II, 14-element, dual frequency log periodic dipole (LPD) antenna array to provide category II/III performance. ASO-433 requested modeling of several terminal airside configurations: airside terminal 4 only, with and without docked and taxiing aircraft; and airside terminals 4 and 2, with and without docked and taxiing aircraft. This modeling effort was performed under project T0605A. The Program Manager is Mr. Edmund A. Zyzys. Additional information regarding this study may be obtained by contacting Messrs. James D. Rambone or John E. Walls at FTS 482-4572 or (609) 484-4572.

## DISCUSSION

### ILS MATH MODELS.

The FAA Technical Center conducts ILS mathematical computer model studies through application of physical optics or geometric theory of diffraction techniques to compute anticipated ILS performance. The modeling for runway 35L localizer was performed using the physical optics localizer model developed by the Transportation Systems Center (TSC) and converted to the Technical Center's mainframe computer. References 1 through 3 describe the modeling technique and implementation. Reference 4 provides validation data for the localizer model.

The coordinate system used in this computer model is a right-handed system with the origin located at the threshold of the runway. The positive x-axis is directed out from the threshold along runway centerline extended, the positive y-axis is directed to the left, the positive z-axis is directed up. Alpha, the angle between the base of a reflector and the x-axis, is measured in the counterclockwise direction. A reflector facing in the negative y-direction has an alpha of  $0^\circ$ . Delta is the angle between the surface of the reflector and the vertical direction. A reflector with a delta of  $0^\circ$  is perpendicular to the ground. Delta is equal to  $-90^\circ$  for a horizontal reflector facing down. A surface illuminated by radio frequency (RF) energy from the antenna is modeled by a rectangular flat or cylindrical surface. The surface is considered to be of infinite conductivity over the total surface and to have zero thickness. This assumption will result in a worst-case performance prediction. The model does not compute multiple reflections or diffractions. Course deviation indicator (CDI) deflections are computed as follows. First, the magnitude and phase of the RF signals arriving at the aircraft location are determined for each surface independently. Next, a resultant RF signal is computed by vectorially combining

the independent signals. CDI deflection is then computed from the resultant RF signal.

#### ILS MODELING PERFORMED.

Figure 1 shows the general orientation of the runway. The TSC localizer model was used to model the effects of the airside terminals and simulated docked and taxiing aircraft. As requested, the Wilcox Mark II, 14-element, dual frequency LPD antenna was modeled at the proposed ILS localizer site. Localizer course structure and clearance orbit computer runs were made for each of the reflective source configurations. Table 1 summarizes the localizer model input data. Antenna currents and phases used for the antenna array are also given in table 1.

The following criteria was used in selecting the surfaces for input to the model: (1) use all surfaces potentially illuminated by direct RF energy from the localizer antenna; (2) the airside terminals can shadow aircraft and each other; (3) aircraft cannot shadow terminals or other aircraft; (4) reflected RF energy is not shadowed; and (5) the effects from other structures on the airport are not considered.

The reflecting surfaces modeled are identified in figure 2. The aircraft (Boeing-747's, Boeing-757's, and Lockheed-1011's) were simulated at specific locations on the airport ramp areas, as given on an airside terminal layout chart, Scheme IIIA, provided by ASO-433. The simulated B-747 aircraft are numbered 17, 18, 19, 25, 26, 27, 28, and 29. The aircraft numbered 10, 11, 12, 13, 14, 20, and 21 are simulated L-1011's. The remaining aircraft were simulated as B-757's. Rectangular plates were used to simulate the aircraft fuselage and tail (figure 3). The taxiing aircraft are modeled as parked in the locations shown. The location and dimensions of all reflecting surfaces are detailed in table 2. Cylinders were used to simulate two corners of the airsites (A and F in figure 2). A cylinder was also used to simulate the Delta ramp operations control tower (surface J in figure 2). Rectangular plates were used to simulate the other reflecting surfaces.

The reflecting source configurations modeled, per ASO-433 request, are as follows:

1. Airside 4 only (surfaces F through J).
2. Airside 4 with aircraft (airside 4 plus aircraft 1 through 16, 24 through 27, and 30 through 33).
3. Airside 4 and 2 with no aircraft (surfaces A through J).
4. Airside 4 and 2 with aircraft (configuration 2 plus airside 2 surfaces A through E, and airside 2 aircraft 1, and 14 through 33).

#### DATA PRESENTATION.

Modeled output results for the localizer are provided on three types of plots: (1) course structure plots, (2) clearance orbit plots, and (3) carrier plus sideband (CSB) and sideband only (SBO) antenna pattern plots. The simulated flightpaths for the course structure runs are centerline approaches starting 60,000 feet from runway threshold. The aircraft crosses the runway threshold at

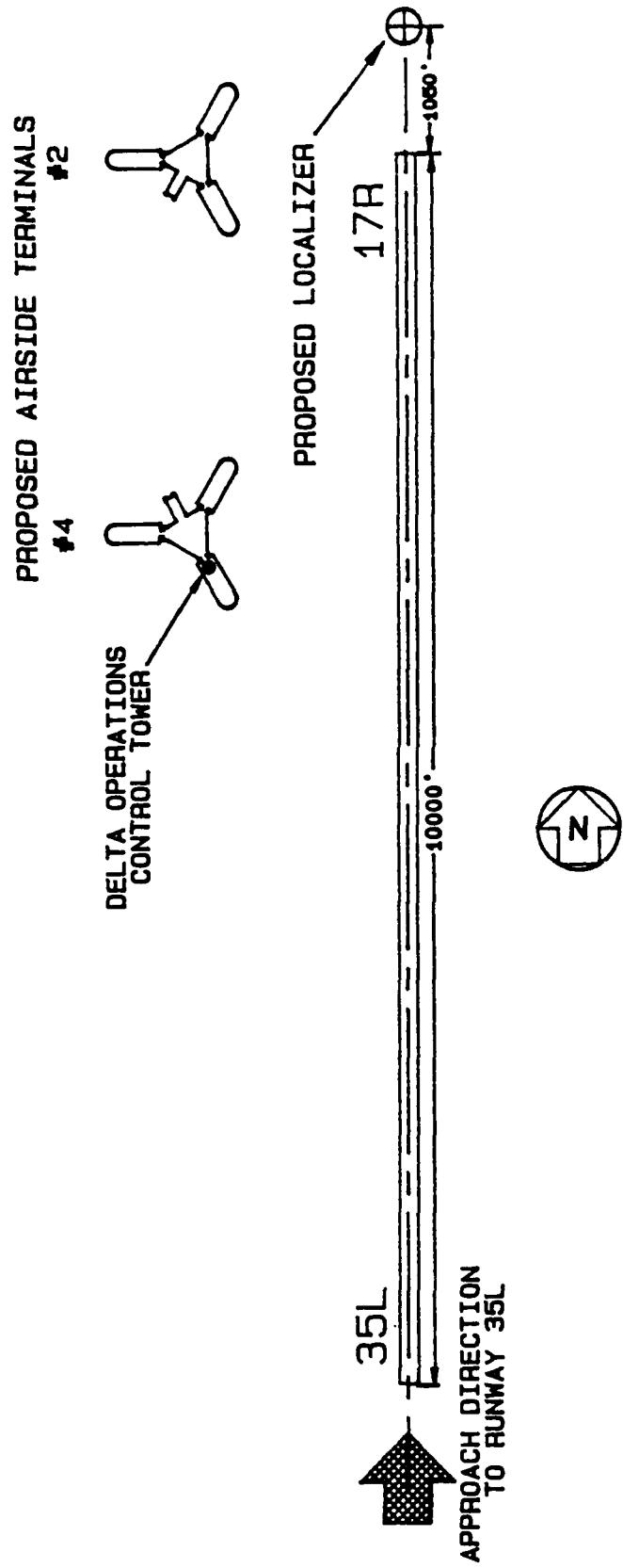


FIGURE 1. ORLANDO RUNWAY 35L, ILS MATH MODELING LAYOUT

TABLE 1. LOCALIZER ANTENNA MODEL INPUT DATA SUMMARY

Localizer Antenna Type:	Wilcox Mark II, LPD 14-Element, Dual Frequency
Runway 35L Length (ft):	10000.0
Distance to Runway 17R End:	1050.0
Frequency (MHz) - Not yet assigned:	110.0
Site Elevation (ft m.s.l.):	86.0
Course Width (deg):	3.63

14-Element LPD Array

Ant. <u>No.</u>	Spacing <u>wave length</u>	Carrier+Sideband		Sideband Only	
		<u>Amplitude</u>	<u>Phase (deg)</u>	<u>Amplitude</u>	<u>Phase (deg)</u>
7L	-4.80	0.160	0	0.367	0
6L	-4.05	0.160	0	0.555	0
5L	-3.30	0.491	0	0.889	0
4L	-2.55	0.491	0	1.000	0
3L	-1.80	0.714	0	1.000	0
2L	-1.05	1.000	0	0.667	0
1L	-0.30	0.893	0	0.222	0
1R	0.30	0.893	0	0.222	180
2R	1.05	1.000	0	0.667	180
3R	1.80	0.714	0	1.000	180
4R	2.55	0.491	0	1.000	180
5R	3.30	0.491	0	0.889	180
6R	4.05	0.160	0	0.555	180
7R	4.80	0.160	0	0.367	180

Clearance Signals

3L	-1.80	0.200	0	0.139	0
2L	-1.05	0.000	0	0.333	0
1L	-0.30	1.000	0	1.000	0
1R	0.30	1.000	0	1.000	180
2R	1.05	0.000	0	0.333	180
3R	1.80	0.200	0	0.139	180

ft - feet

MHz - megahertz

m.s.l. - mean sea level

deg - degree

AIRSIDE 4

AIRSIDE 2

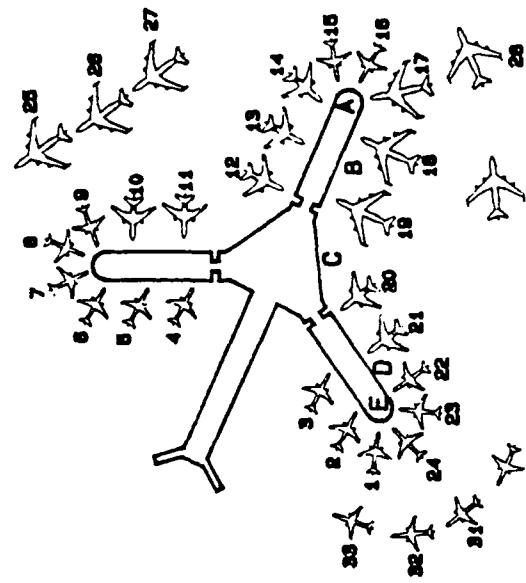


FIGURE 2. ORLANDO RUNWAY 35L, PROPOSED AIRSIDE TERMINALS AND SIMULATED DOCKED AND TAXIING AIRCRAFT DETAILS, SCHEME IIIA

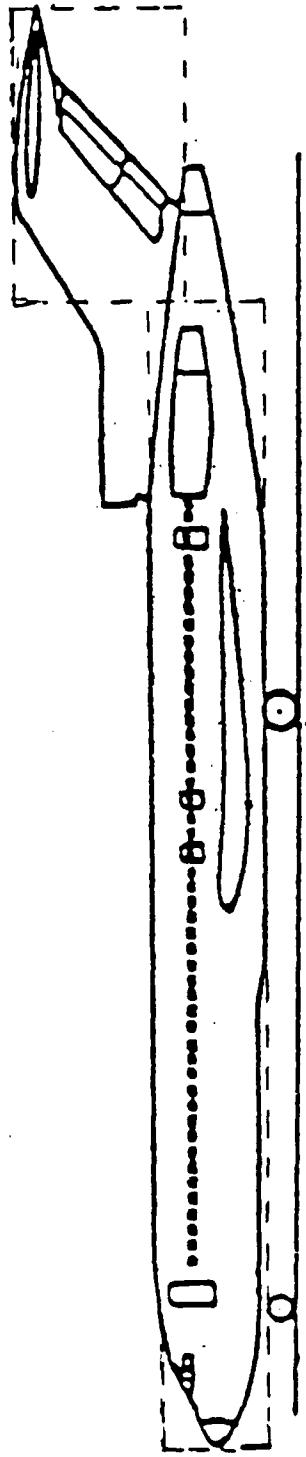


FIGURE 3. TYPICAL AIRCRAFT REFLECTOR PLATE SILHOUETTE

TABLE 2. LOCALIZER REFLECTING SURFACES DATA SUMMARY

<u>Airside 4</u>	Coordinates (ft)*			Alpha (deg)	Delta (deg)	Width (ft)	Height (ft)
	X	Y	Z**				
F	-7467	-1467	5	0.0	0.0	95	32
G	-6930	-1619	5	180.0	0.0	312	43
H	-6585	-1514	5	210.2	0.0	340	32
I	-6411	-1427	5	183.6	0.0	48	32
J	-6810	-1686	5	0.0	0.0	27	103
<u>Aircraft</u> <u>Airside 4</u>	Coordinates (ft)*			Alpha (deg)	Delta (deg)	Width (ft)	Height (ft)
	X	Y	Z**				
1	-7040	-2498	11	229.4	0.0	134	15
	-7090	-2555	18	229.4	0.0	23	32
2	-7082	-2369	11	209.3	0.0	136	15
	-7149	-2407	18	209.3	0.0	19	32
3	-7081	-2206	11	209.3	0.0	134	15
	-7148	-2243	18	209.3	0.0	20	32
4	-7317	-1658	11	207.6	0.0	134	15
	-7386	-1694	18	207.6	0.0	22	32
5	-7455	-1563	11	207.8	0.0	135	15
	-7523	-1599	18	207.8	0.0	20	32
6	-7586	-1466	11	208.6	0.0	133	15
	-7653	-1503	18	208.6	0.0	21	32
7	-7608	-1349	11	172.5	0.0	134	15
	-7685	-1339	18	172.5	0.0	21	32
8	-7556	-1251	11	303.2	0.0	133	15
	-7597	-1186	18	303.2	0.0	22	32
9	-7446	-1235	11	253.4	0.0	133	15
	-7425	-1161	18	253.4	0.0	20	32
10	-7306	-1312	13	235.0	0.0	131	20
	-7258	-1243	21	235.0	0.0	34	44
11	-7149	-1411	13	233.6	0.0	130	20
	-7100	-1345	21	233.6	0.0	33	44
12	-6815	-1476	13	299.9	0.0	133	20
	-6854	-1405	21	299.9	0.0	31	44
13	-6652	-1379	13	299.2	0.0	131	20
	-6693	-1307	21	299.2	0.0	33	44
14	-6504	-1287	13	285.5	0.0	133	20
	-6524	-1208	21	285.5	0.0	32	44
15	-6365	-1266	11	245.2	0.0	133	15
	-6332	-1195	18	245.2	0.0	22	32
16	-6266	-1341	11	209.6	0.0	133	15
	-6199	-1302	18	209.6	0.0	20	32

TABLE 2. LOCALIZER REFLECTING SURFACES DATA SUMMARY (CONTINUED)

<u>Aircraft</u>	<u>Coordinates (ft)*</u>			<u>Alpha</u>	<u>Delta</u>	<u>Width</u>	<u>Height</u>
<u>Airside 4</u>	<u>X</u>	<u>Y</u>	<u>Z**</u>	<u>(deg)</u>	<u>(deg)</u>	<u>(ft)</u>	<u>(ft)</u>

24	-6934	-2536	11	278.9	0 0	133	15
	-6922	-2612	18	278.9	0.0	21	32
25	-7451	-897	12	180.0	0.0	195	27
	-7335	-897	23	180.0	0.0	38	46
26	-7191	-919	12	180.0	0.0	196	27
	-7075	-919	23	180.0	0 0	36	46
27	-6936	-917	12	180.0	0.0	194	27
	-6821	-918	23	180.0	0.0	37	46
30	-6689	-2823	11	210.4	0.0	139	15
	-6620	-2784	18	210.4	0.0	18	32
31	-6920	-2871	11	180.0	0.0	135	15
	-6841	-2871	18	180.0	0.0	23	32
32	-7114	-2820	11	150.5	0.0	135	15
	-7046	-2860	18	150.5	0.0	22	32
33	-7266	-2656	11	303.9	0.0	132	15
	-7223	-2719	18	303.9	0.0	21	32

<u>Aircraft</u>	<u>Coordinates (ft)*</u>			<u>Alpha</u>	<u>Delta</u>	<u>Width</u>	<u>Height</u>
<u>Airside 2</u>	<u>X</u>	<u>Y</u>	<u>Z**</u>	<u>(deg)</u>	<u>(deg)</u>	<u>(ft)</u>	<u>(ft)</u>

A	-10506	-1470	5	0.0	0.0	95	32
B	-10329	-1520	5	150.3	0.0	345	32
C	- 9981	-1625	5	180.6	0.0	312	43
D	- 9630	-1514	5	209.7	0.0	345	32
E	- 9452	-1424	5	183.4	0.0	51	32

<u>Aircraft</u>	<u>Coordinates (ft)*</u>			<u>Alpha</u>	<u>Delta</u>	<u>Width</u>	<u>Height</u>
<u>Airside 2</u>	<u>X</u>	<u>Y</u>	<u>Z**</u>	<u>(deg)</u>	<u>(deg)</u>	<u>(ft)</u>	<u>(ft)</u>

1	- 9326	-1383	11	174.5	0.0	136	15
	- 9248	-1389	18	174.5	0.0	23	32
14	-10626	-1639	13	229.3	0.0	131	20
	-10680	-1702	21	229.3	0.0	32	44
15	-10723	-1538	11	189.7	0.0	134	15
	-10799	-1551	18	189.7	0.0	23	32
16	-10717	-1413	11	154.7	0.0	134	15
	-10788	-1380	18	154.7	0.0	23	32
17	-10621	-1312	12	282.0	0.0	194	27
	-10646	-1198	23	282.0	0.0	36	46
18	-10413	-1350	12	247.3	0.0	196	27
	-10368	-1243	23	247.3	0.0	37	46
19	-10190	-1443	12	247.3	0.0	193	27
	-10146	-1335	23	247.3	0.0	39	46
20	- 9869	-1465	13	304.4	0.0	132	20

TABLE 2. LOCALIZER REFLECTING SURFACES DATA SUMMARY (CONTINUED)

<u>Aircraft</u>	<u>Coordinates (ft)*</u>			<u>Alpha</u>	<u>Delta</u>	<u>Width</u>	<u>Height</u>
<u>Airside 2</u>	<u>X</u>	<u>Y</u>	<u>Z**</u>	<u>(deg)</u>	<u>(deg)</u>	<u>(ft)</u>	<u>(ft)</u>
21	- 9916	- 1398	21	304.4	0.0	32	44
	- 9716	- 1355	13	304.3	0.0	134	20
	- 9764	- 1288	21	304.3	0.0	32	44
22	- 9581	- 1263	11	304.1	0.0	135	15
	- 9624	- 1200	18	304.1	0.0	19	32
23	- 9467	- 1229	11	264.8	0.0	134	15
	- 9460	- 1153	18	264.8	0.0	21	32
24	- 9357	- 1273	11	224.1	0.0	134	15
	- 9301	- 1219	18	224.1	0.0	22	32
25	- 10399	- 2638	12	125.1	0.0	197	27
	- 10465	- 2542	23	125.1	0.0	36	46
26	- 10529	- 2412	12	124.4	0.0	196	27
	- 10597	- 2317	23	124.4	0.0	37	46
27	- 10679	- 2206	12	125.3	0.0	195	27
	- 10745	- 2111	23	125.3	0.0	37	46
28	- 10765	- 1043	12	205.7	0.0	195	27
	- 10659	- 995	23	205.7	0.0	39	46
29	- 10300	- 951	12	185.0	0.0	194	27
	- 10185	- 942	23	185.0	0.0	38	46
30	- 9259	- 907	11	334.9	0.0	133	15
	- 9329	- 875	18	334.9	0.0	21	32
31	- 9091	- 1067	11	304.1	0.0	133	15
	- 9134	- 1004	18	304.1	0.0	21	32
32	- 9018	- 1255	11	274.5	0.0	132	15
	- 9025	- 1178	18	274.5	0.0	21	32
33	- 9067	- 1475	11	249.6	0.0	132	15
	- 9040	- 1402	18	249.6	0.0	21	32

\* - Midpoint of base of surface referenced to threshold of runway 35L.

\*\* - Referenced to base of antenna.

the threshold crossing height and continues at this altitude to a point just short of the stop end of the runway. Distances shown on the horizontal axis of the course structure plots are referenced to the approach threshold. Negative values are shown for distances between the threshold and the localizer. Positive values apply to distances on the approach path toward the outer marker. Angular values on the horizontal axes of the CSB and SBO antenna pattern plots and on the clearance orbit plots were run with flight arcs of 35,000 feet at altitudes of 1,000 feet with respect to the localizer site.

The vertical axes of the course structure and clearance orbit plots are the model output values of CDI deflection in microamps (0.4-second time constant applied for smoothing). The vertical axes of the antenna pattern plots use a relative scale with the pattern normalized to its peak value. The usual range for the vertical scale of modeled course structure data plots is +40 to -40 microamps. This range has been reduced to +10 to -10 microamps for the course structure plots provided in this study in order to better display small values of CDI deflection. This choice of scale eliminates the display of category I limits from the plot and shows only the final segment of the category II tolerance limits. Category III tolerance limits (not shown) extend the 5-microamp tolerance shown for category II performance to a point on the runway 3,000 feet from threshold. The limits then increase linearly to 10 microamps at a point which is 2,000 feet from the stop end of the runway.

Modeled localizer output data are provided in figures 4 through 15. Figures 4 through 6 provide computed performance results with airside 4 as the only reflecting source. Modeled course structure is plotted in figure 4. Computed clearance orbit results are given in figure 5. Figure 6 shows the computed CSB and SBO antenna pattern plots. Figures 7 through 9 provide similar plots for the reflecting surface configuration consisting of airside 4 with simulated docked and taxiing aircraft. Figures 10 through 12 show computed performance results for the two airside terminals with no simulated aircraft. The computed performance results for the reflecting surface combination consisting of both airsides 4 and 2 with simulated docked and taxiing aircraft at each airside are provided in figures 13 through 15.

#### DATA ANALYSIS.

Modeled course structure results for airside 4 alone and air sides 4 and 2 with no aircraft (figures 4 and 10, respectively) show computed CDI deflections that are well within category II/III course structure tolerance limits. Figure 7 (airside 4 with docked and taxiing aircraft) and figure 13 (airsides 4 and 2 with docked and taxiing aircraft) course structure results show computed CDI deflections that are slightly larger, but still well within the category II/III tolerance limits. The computed clearance orbit plots (figures 5, 8, 11, and 14) indicate satisfactory linearity, course crossover, and clearance levels. Figures 6, 9, 12, and 15, CSB and SBO antenna patterns for the Mark II antenna array, show some roughness in the computed clearance signals of the pattern.

#### CONCLUSIONS

Modeled results indicate that category II/III localizer performance should be obtained for runway 35L with the Wilcox Mark II, 14-element, dual frequency log periodic dipole (LPD) antenna array with both airside terminals and docked and taxiing aircraft located as proposed. Computed clearance orbit results indicate satisfactory linearity, course crossover, and clearance levels.

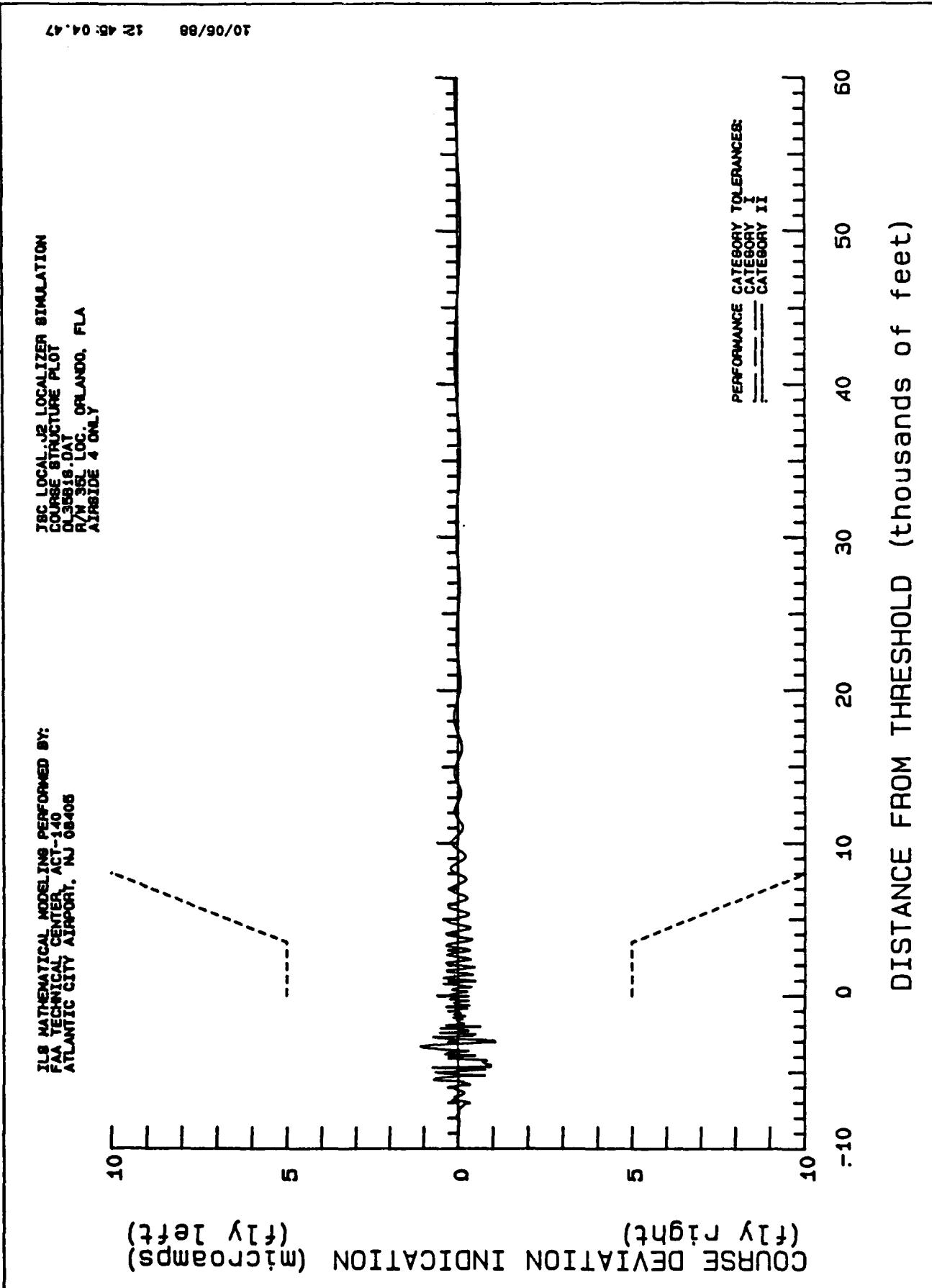


FIGURE 4. COURSE STRUCTURE, ORLANDO RUNWAY 35L LOCALIZER, AIRSIDE TERMINAL 4,  
 NO AIRCRAFT

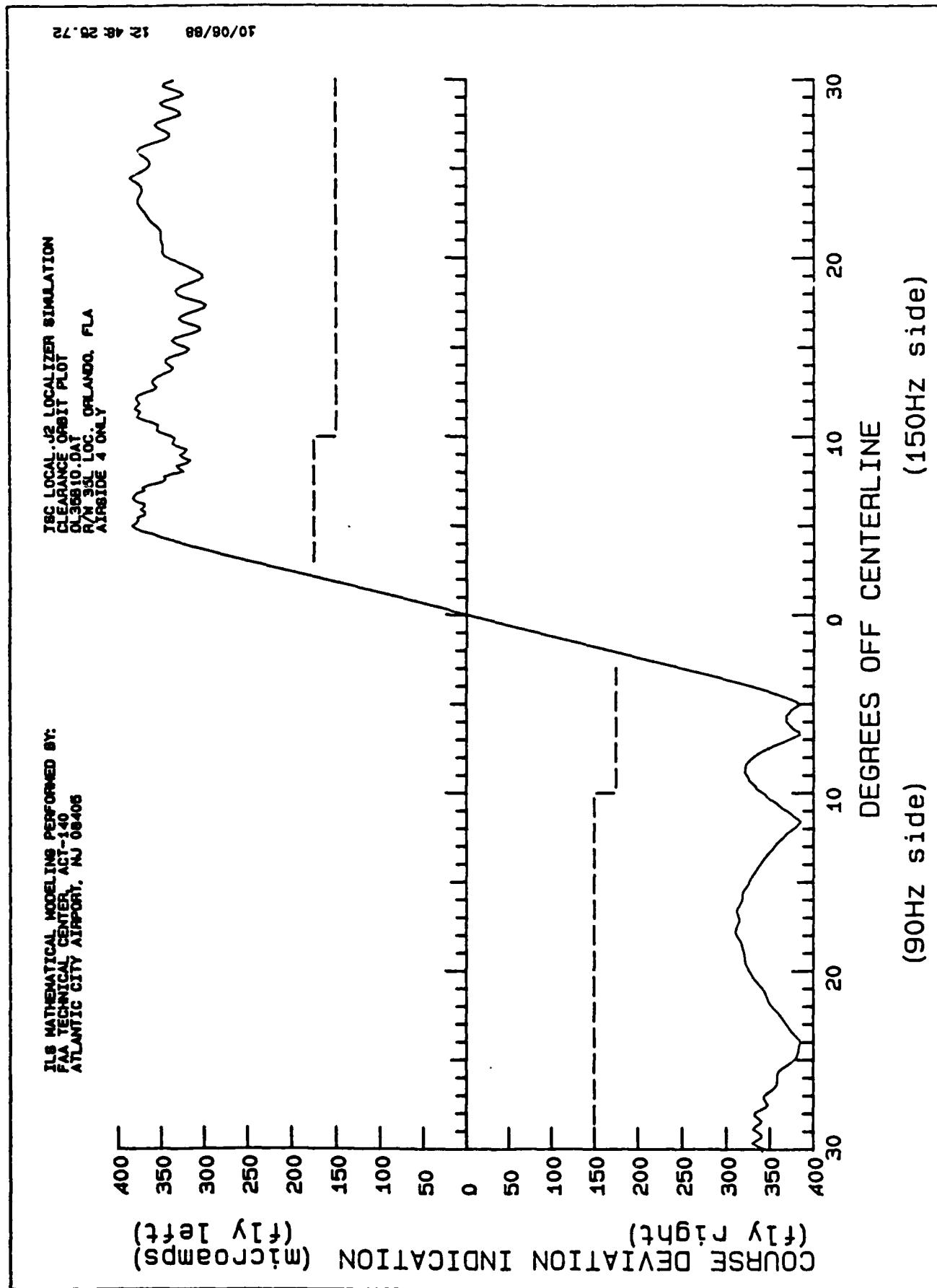


FIGURE 5. CLEARANCE ORBIT, ORLANDO RUNWAY 35L LOCALIZER, AIRSIDE TERMINAL 4,  
 NO AIRCRAFT

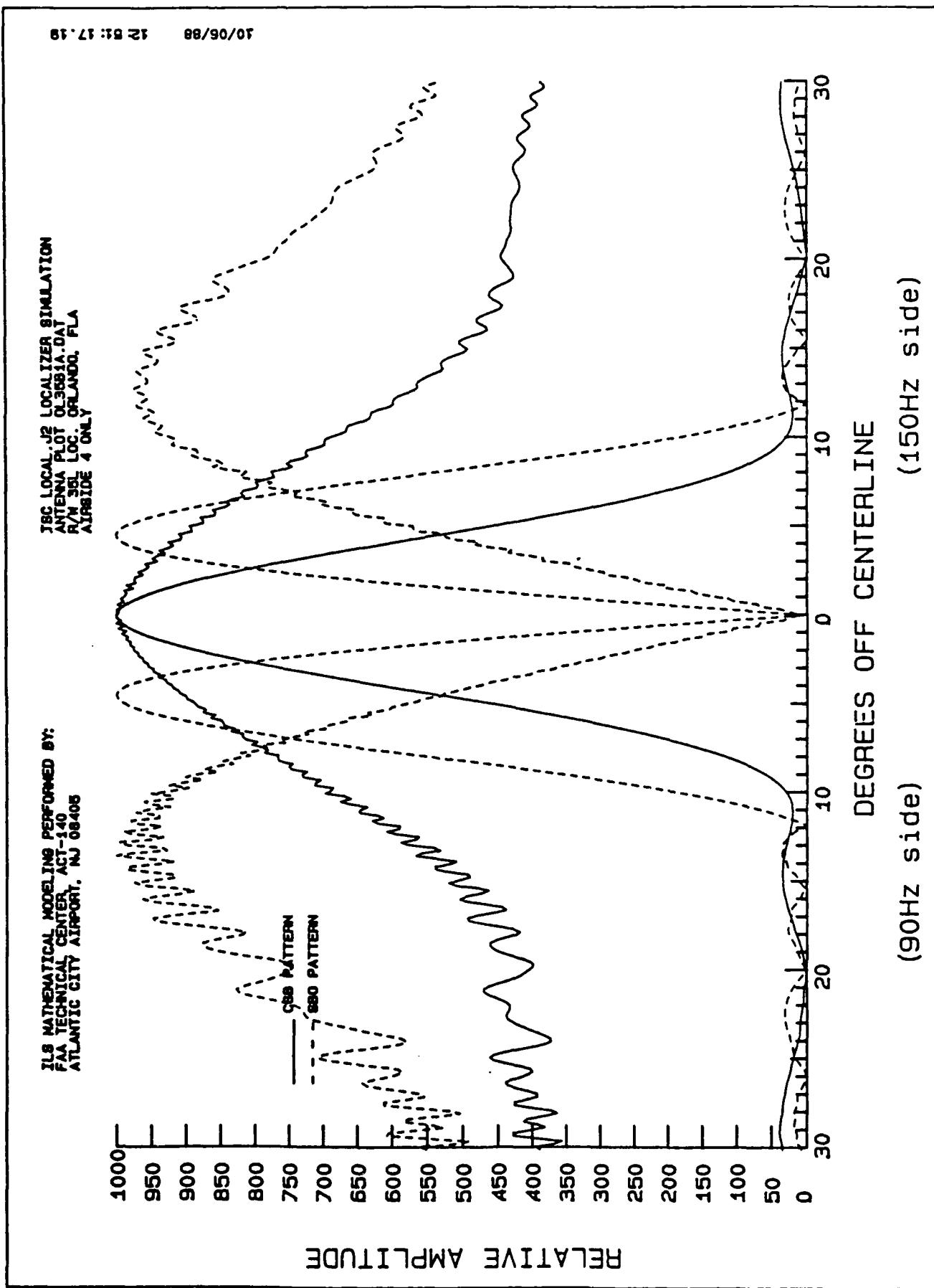


FIGURE 6. CSB AND SBO ANTENNA PATTERNS, ORLANDO RUNWAY 35L LOCALIZER, AIRSIDE TERMINAL 4, NO AIRCRAFT

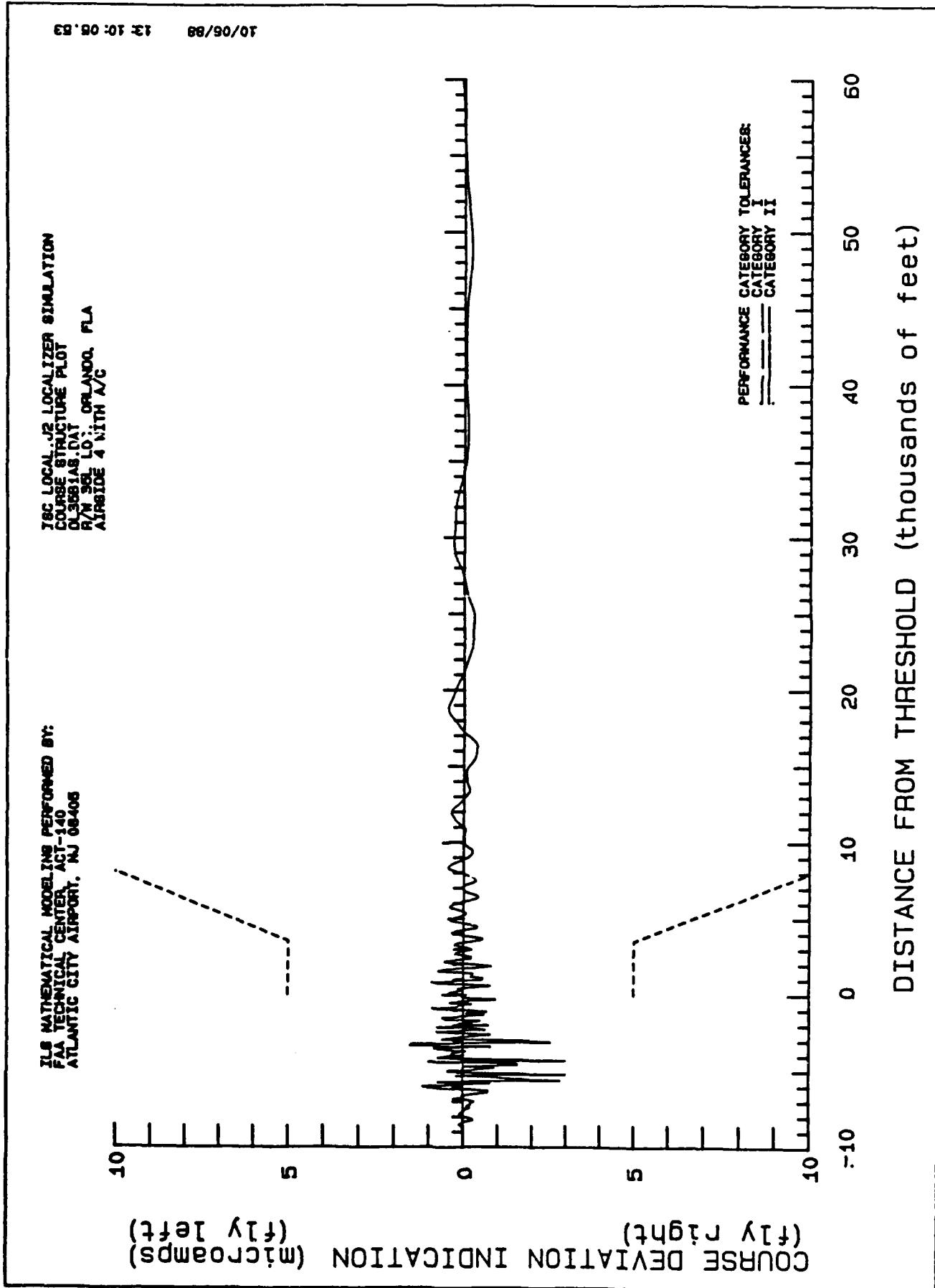


FIGURE 7. COURSE STRUCTURE, ORLANDO RUNWAY 35L LOCALIZER, AIRSIDE  
 TERMINAL 4, DOCKED AND TAXIING AIRCRAFT

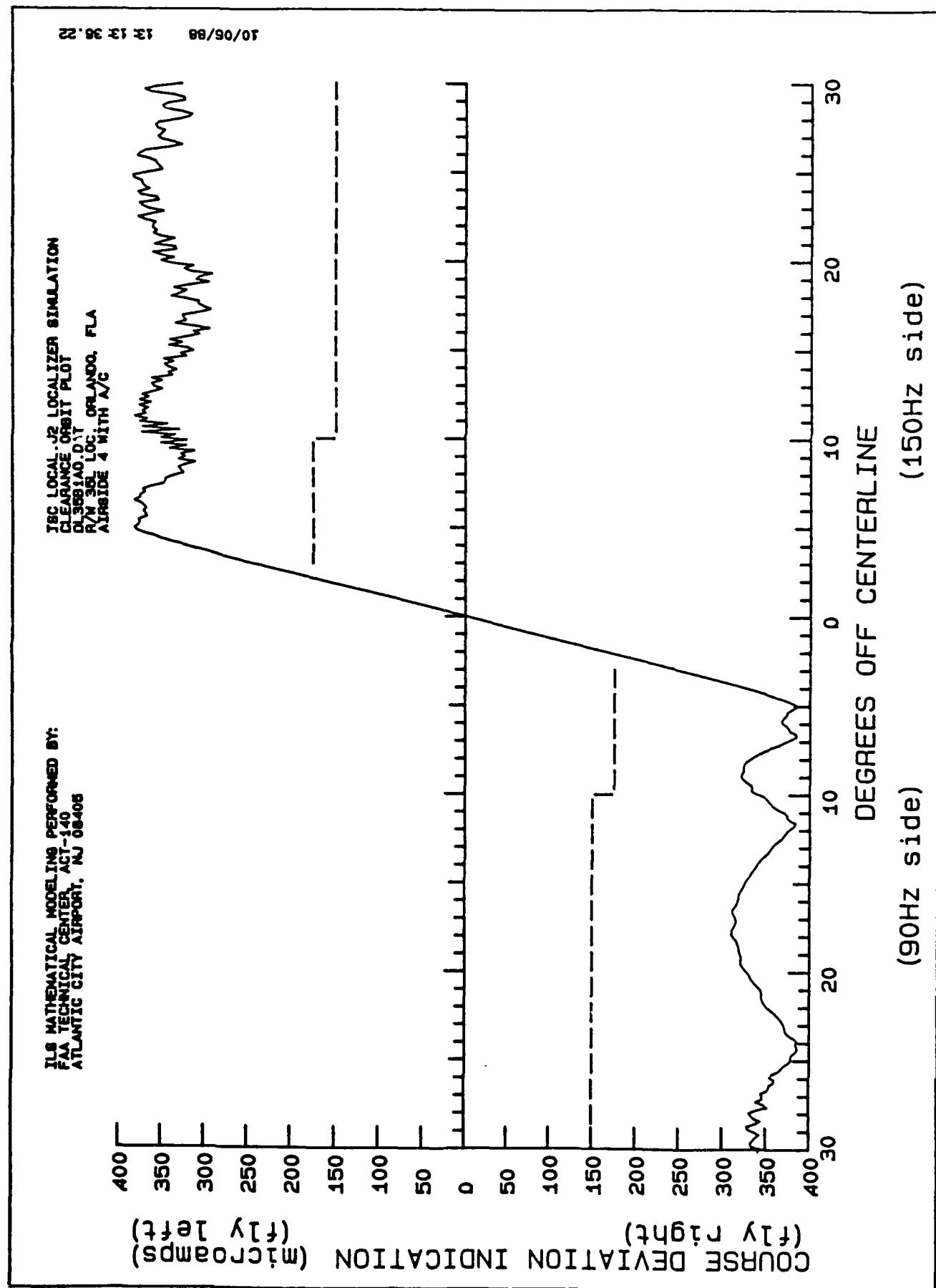


FIGURE 8. CLEARANCE ORBIT, ORLANDO RUNWAY 35L LOCALIZER, AIRSIDE TERMINAL 4, DOCKED AND TAXIING AIRCRAFT

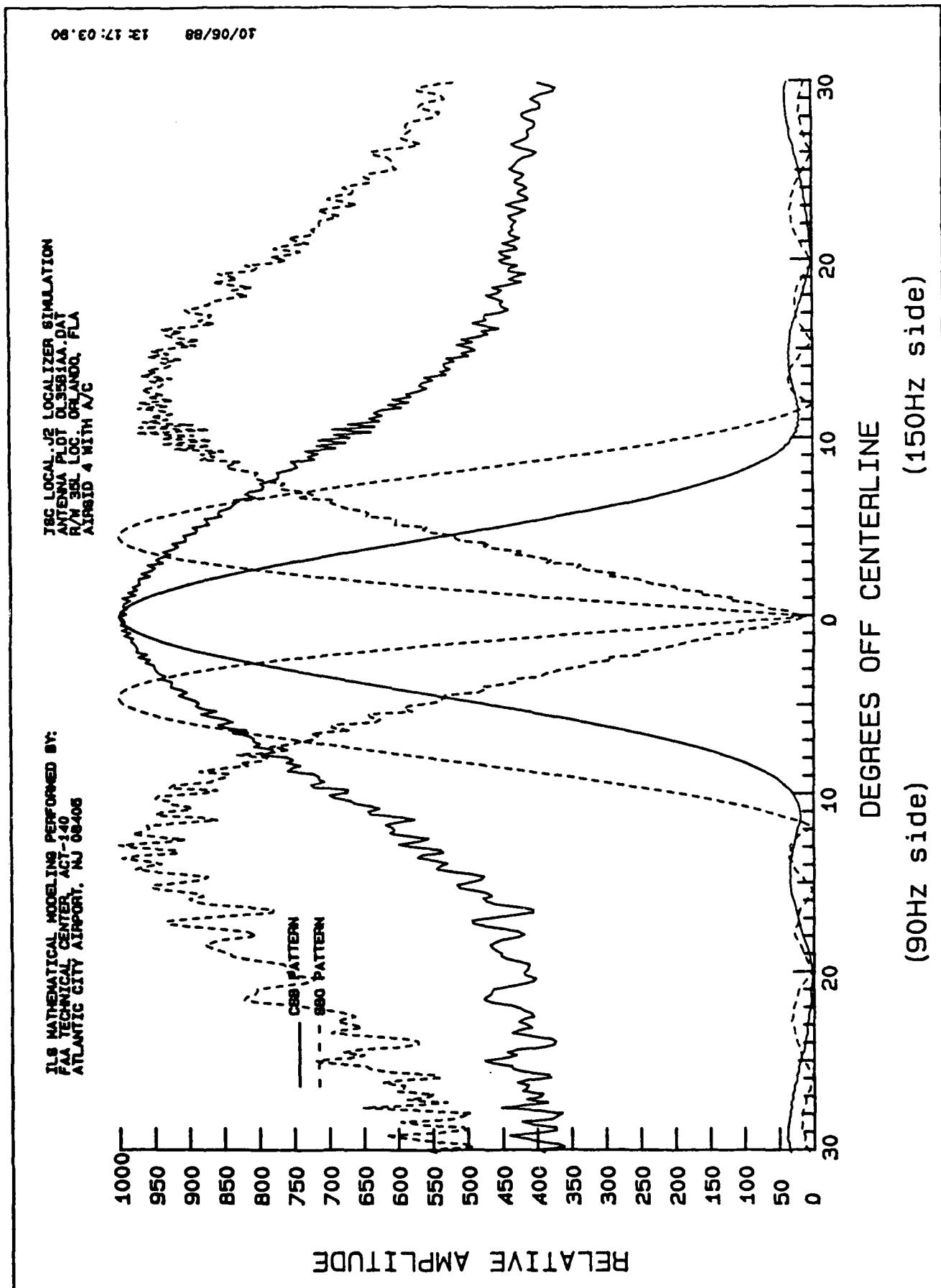


FIGURE 9. CSB AND SBO ANTENNA PATTERNS, ORLANDO RUNWAY 35L LOCALIZER,  
 AIRSIDE TERMINAL 4. DOCKED AND TAXIING AIRCRAFT

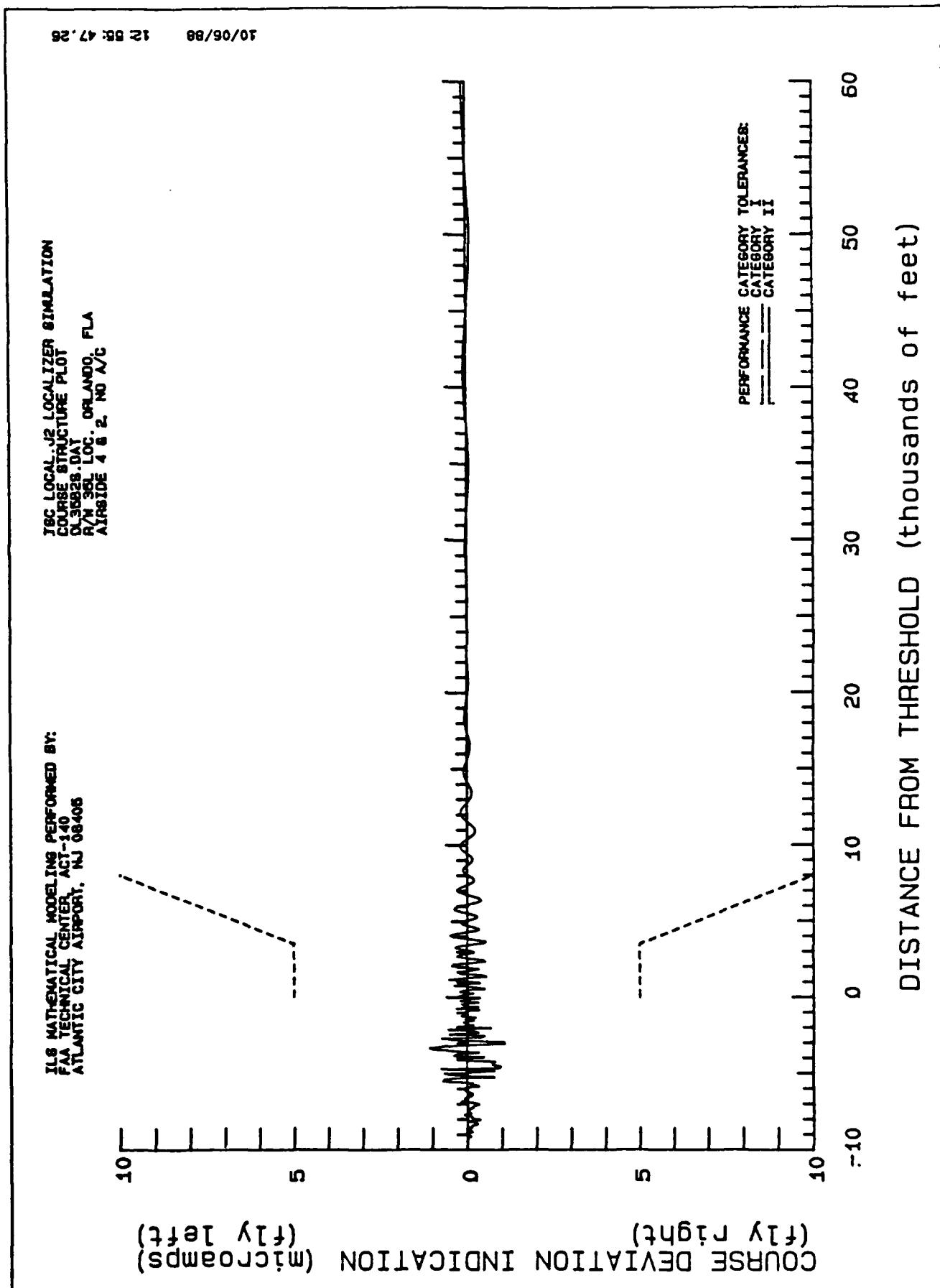
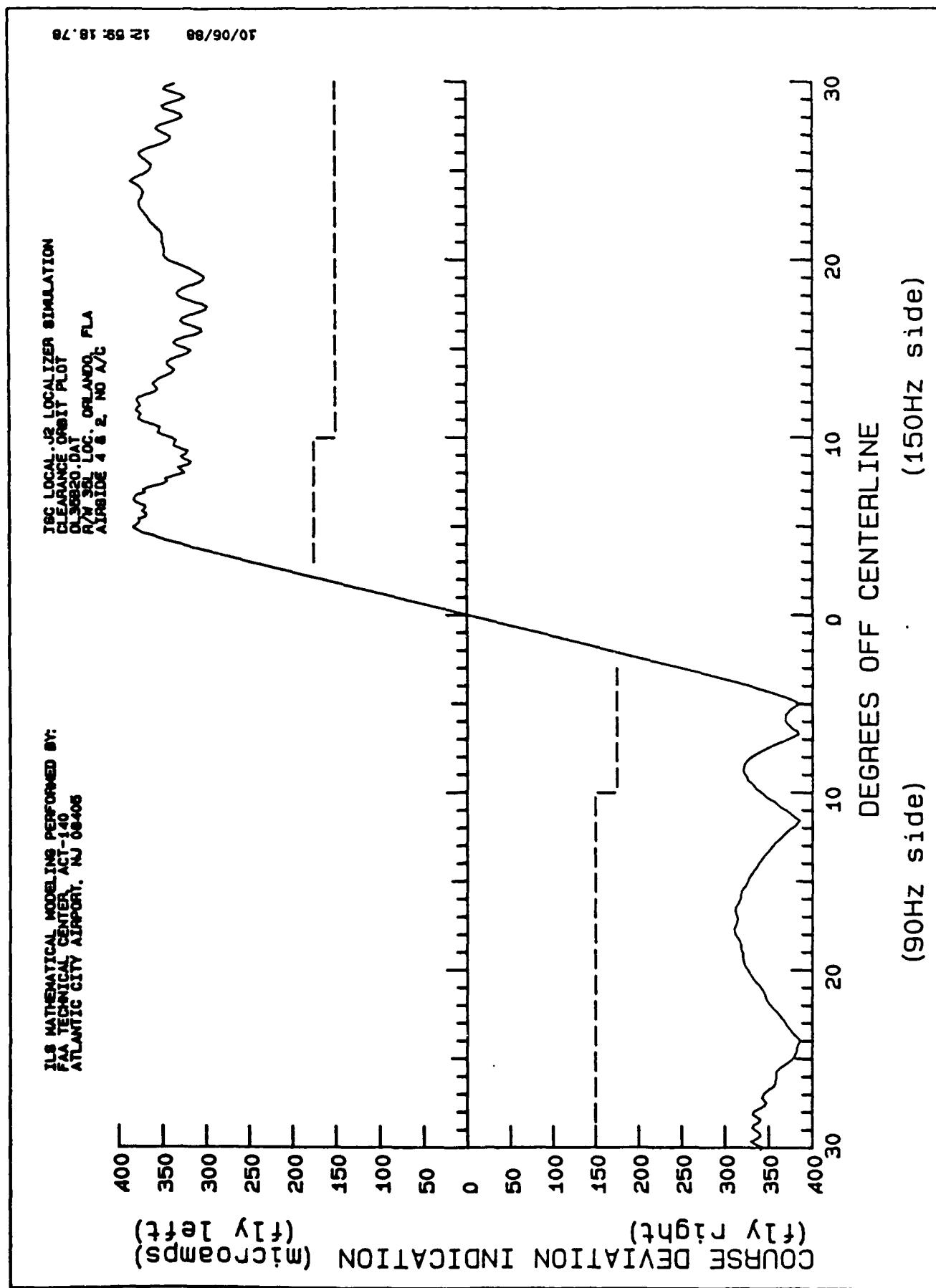


FIGURE 10. COURSE STRUCTURE, ORLANDO RUNWAY 35L LOCALIZER, AIRSIDE  
 TERMINALS 4 AND 2, NO AIRCRAFT



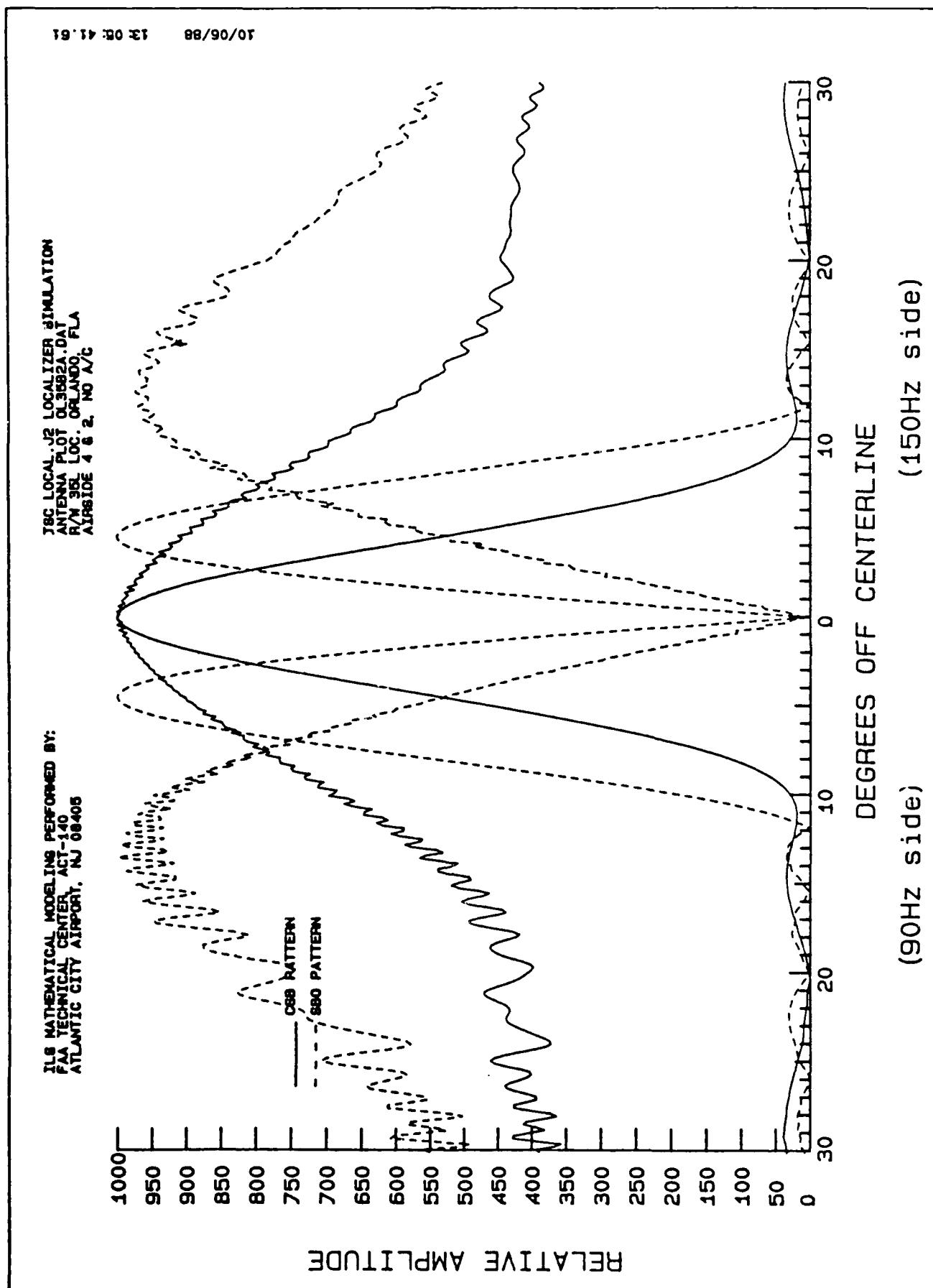


FIGURE 12. CSB AND SBO ANTENNA PATTERNS, ORLANDO RUNWAY 35L LOCALIZER,  
 AIRSIDE TERMINALS 4 AND 2, NO AIRCRAFT

10/06/88 13 22 07.80

JBC LOCAL J2 LOCALIZER SIMULATION  
COURSE STRUCTURE PLOT  
D:\35L2\AS.DAT  
R/W 35L LOC. ORLANDO, FLA  
AIRSIDE 4 & 2 WITH A/c

ILS MATHEMATICAL MODELING PERFORMED BY:  
FAA TECHNICAL CENTER ACT-140  
ATLANTIC CITY AIRPORT, NJ 08406

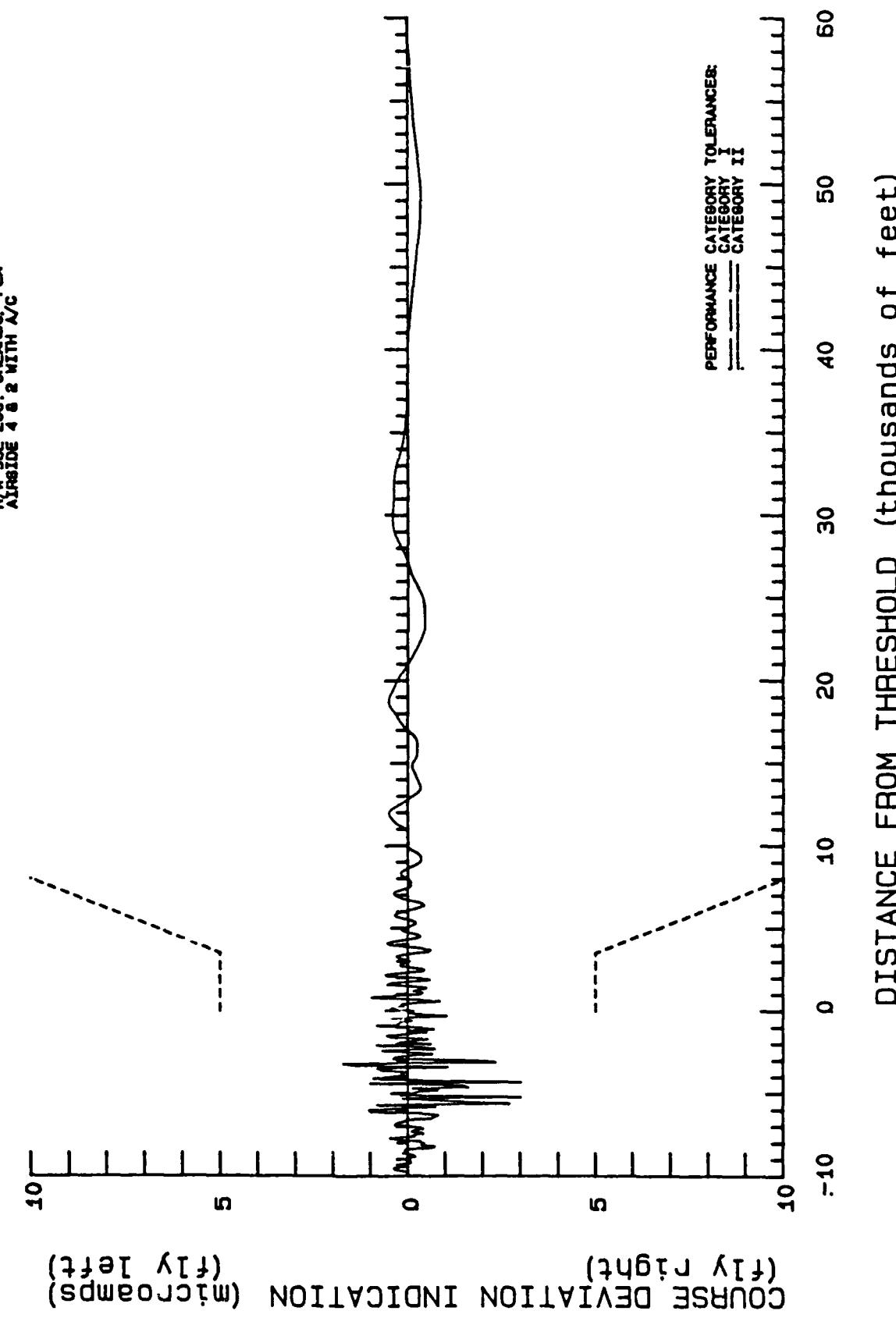


FIGURE 13. COURSE STRUCTURE, ORLANDO RUNWAY 35L LOCALIZER, AIRSIDE TERMINALS 4 AND 2, DOCKED AND TAXIING AIRCRAFT

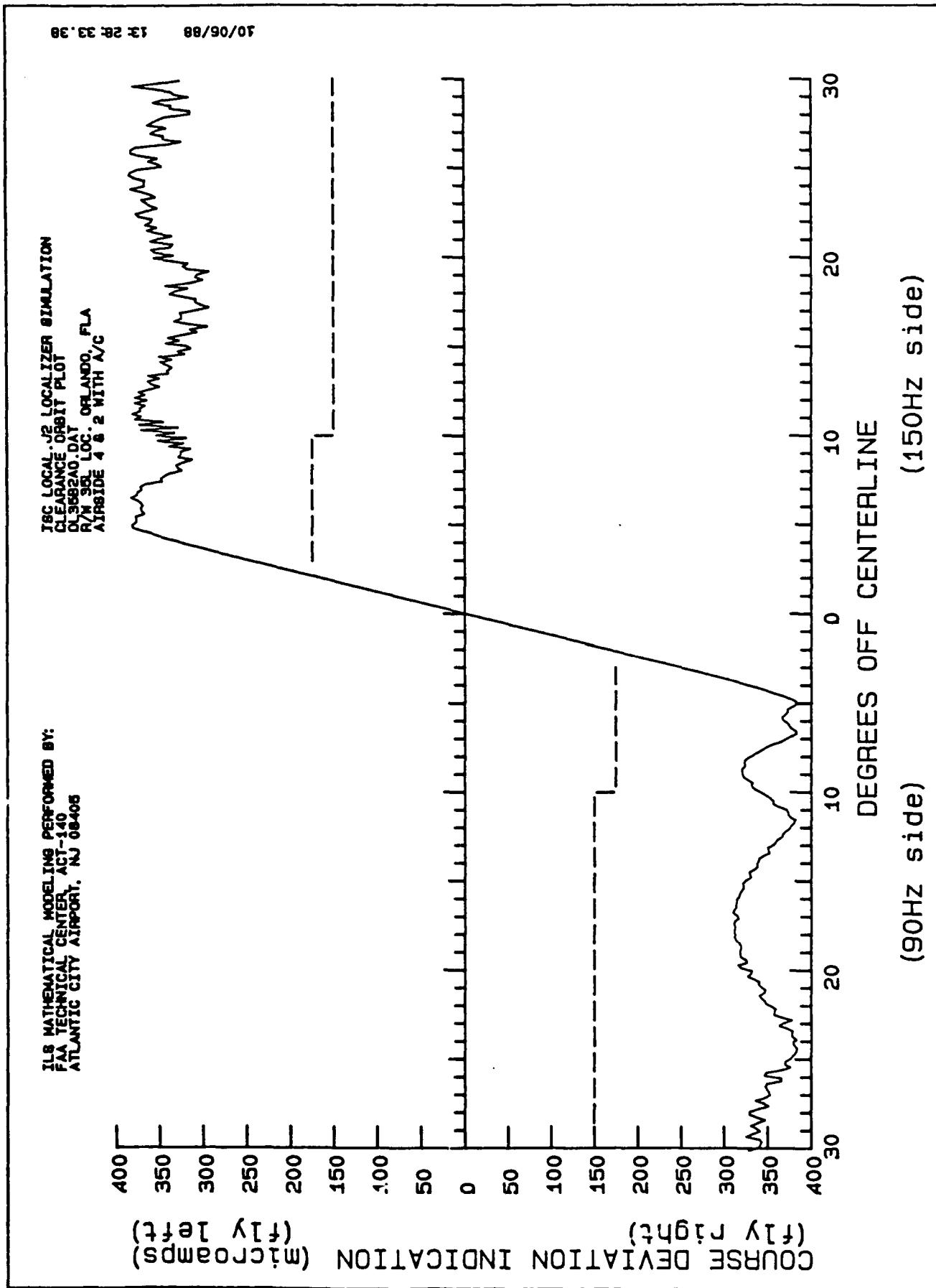


FIGURE 14. CLEARANCE ORBIT, ORLANDO RUNWAY 35L LOCALIZER, AIRSIDE  
 TERMINALS 4 AND 2, DOCKED AND TAXIING AIRCRAFT

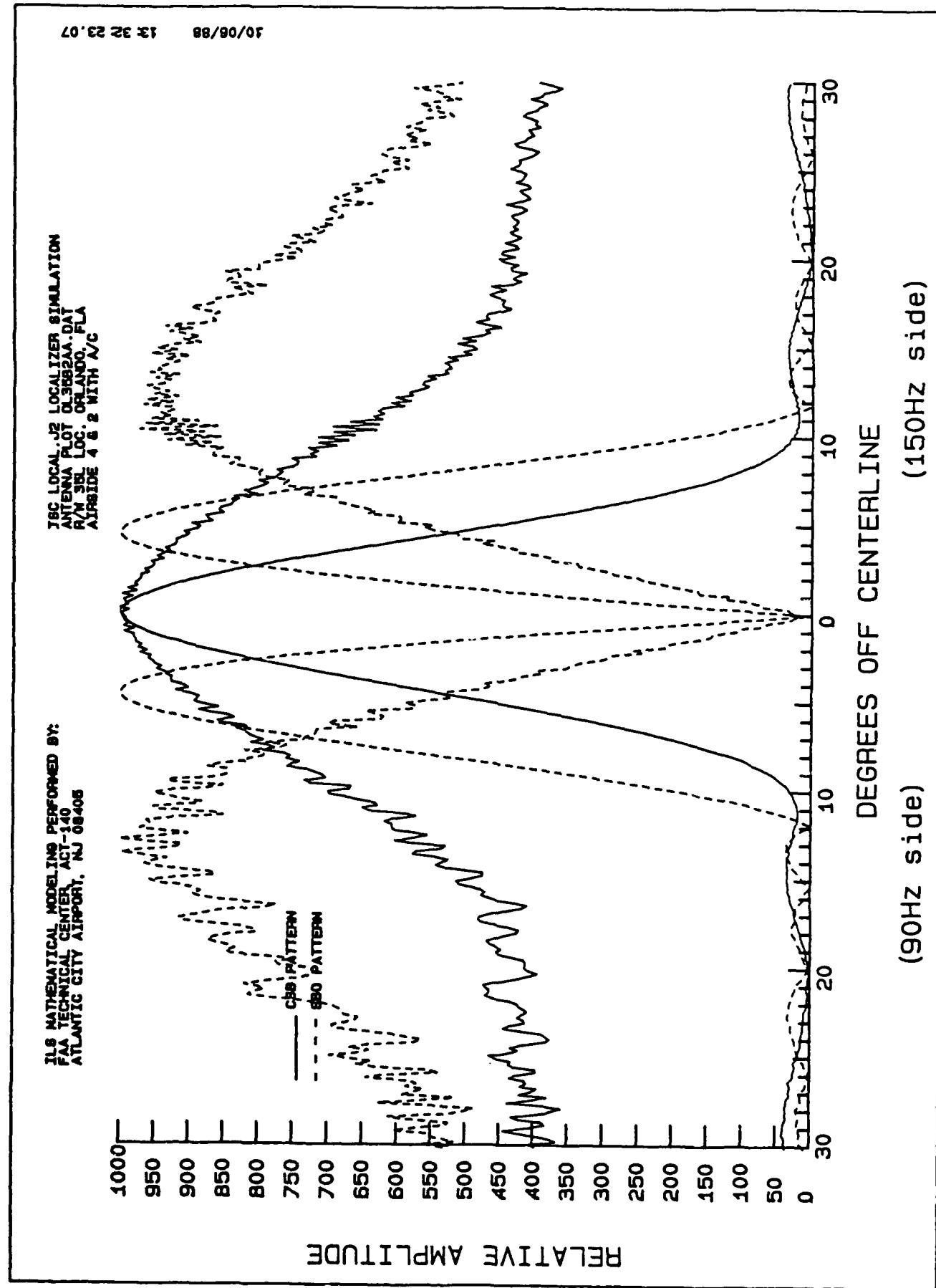


FIGURE 15. CSB AND SBO ANTENNA PATTERNS, ORLANDO RUNWAY 35L LOCALIZER, AIRSIDE TERMINALS 4 AND 2, DOCKED AND TAXIING AIRCRAFT

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2. Chin, G., et al., User's Manual for ILSLOC: Simulation for Derogation Effects on the Localizer Portion of the Instrument Landing System, Report DOT/FAA-RD-73-13, 1973.
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